FIELDIANA · GEOLOGY

Published by

CHICAGO NATURAL HISTORY MUSEUM

Volume 14 JULY 31, 1963 No. 8

Parasaurolophus cyrtocristatus, a Crested Hadrosaurian Dinosaur from New Mexico

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INTRODUCTION

The paleontological contributions of the Sternberg family are well known to paleontologists and laymen alike. Scores of fine fossil vertebrates are now exhibited in many museums both in America and abroad, as a result of their efforts over a span of several decades. One of the Sternberg discoveries is the specimen herein described: a very fine skeleton of *Parasaurolophus*, which now resides in the collections of Chicago Natural History Museum. It is also appropriate to note here that all three of the currently known specimens of this genus, constituting three different species, were discovered and collected by one of the Sternbergs (*P. walkeri* by Mr. Levi Sternberg and *P. tubicen* and *P. cyrtocristatus* by Mr. C. H. Sternberg).

The present specimen was collected in 1923 from the Fruitland formation of northwestern New Mexico, and was subsequently purchased by Chicago Natural History Museum. It has recently been prepared and now is being readied for exhibition. A preliminary study (Ostrom, 1961a), assigning this specimen to a new species (*P. cyrtocristatus*[1]), is the only prior notice of this discovery to be published, although reference is made to the specimen in my report on hadrosaurian cranial morphology (Ostrom, 1961b).

My sincere thanks go to Dr. Rainer Zangerl, of Chicago Natural History Museum, for bringing this specimen to my attention and for his permission to study and describe the material. A grant

[1] *Kuptós*, curved, + *cristatus*, crested.

Library of Congress Catalog Card Number: 63-14122

No. 971

from the Karl Patterson Schmidt Fund of the Museum financed this study and is hereby gratefully acknowledged.

In this report, names of institutions are abbreviated as follows:

CNHM, Chicago Natural History Museum
AMNH, American Museum of Natural History
ROM, Royal Ontario Museum, Toronto

SYSTEMATIC DESCRIPTION

Order **Ornithischia**

Suborder **Ornithopoda**

Family **Hadrosauridae**

Subfamily **Lambeosaurinae**[1]

Genus **Parasaurolophus**

Parasaurolophus cyrtocristatus, new species

Diagnosis.—Crested lambeosaurine with a caudally prolonged, strongly recurved, parallel-sided, cranial (narial) crest. The crest is similar to that of *P. walkeri* (and also that of *P. tubicen*), but is approximately one third as long, extending only 260 mm. behind the occiput (fig. 83). The crest curves strongly downward behind the occiput, rather than extending dorso-caudally in a gentle arc as in the other species of *Parasaurolophus*. It is composed almost entirely of the premaxillae, the nasals apparently being small elements restricted to the posterior basal portion of the crest. Paired narial passages, separated by a median septum, extend over the total crest length, looping back beneath themselves at the crest extremity and extending forward along the ventral part of the crest to a common orifice in the interorbital region. The post-cranial skeleton is very similar to that of *P. walkeri,* except that all limb dimensions exceed those of the latter species. Unlike *P. walkeri,* however, the radius length (585 mm.) exceeds the length of the humerus (565 mm.).

Type specimen.—CNHM P27393, a nearly complete skeleton and fragmentary skull. The cranial crest and the dorso-caudal part of the cranium are the principal parts of the skull preserved. A fragment of the left dentary was also recovered.

[1] The classification followed here, in which three hadrosaurian subfamilies (Hadrosaurinae, Lambeosaurinae, and Saurolophinae) are recognized, is the one I formerly proposed (Ostrom, 1961b).

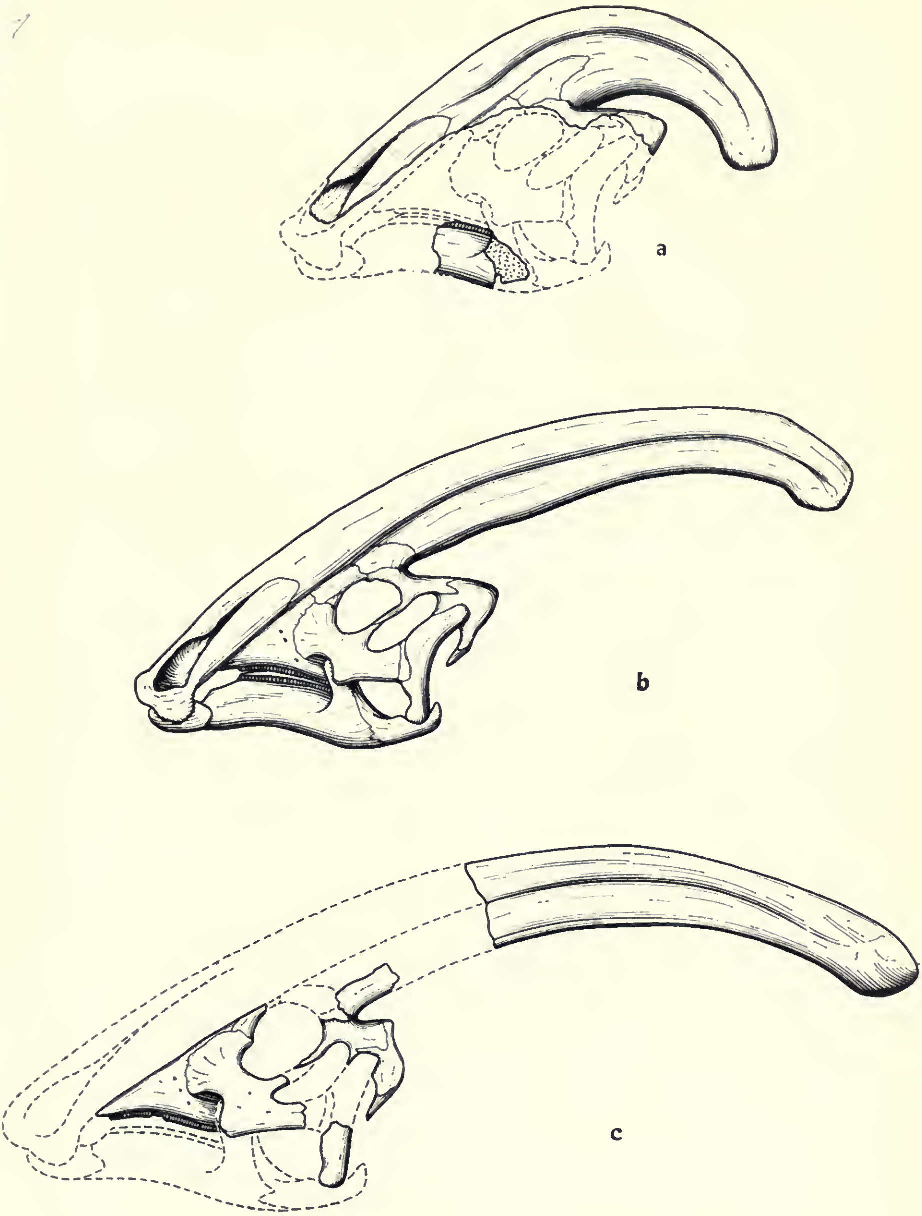

FIG. 83. Comparison of skulls and crests of three species of *Parasaurolophus*. *a*, *P. cyrtocristatus* (CNHM no. P27393). *b*, *P. walkeri* (ROM no. 768). *c*, *P. tubicen* (University of Upsala, Sweden). (All approximately $\times$ 1/16; from Ostrom, 1961a.)

Horizon and locality.—Collected near Coal Creek, eight miles southeast of Tsaya, McKinley County, New Mexico. (This locality is not to be confused with a "Coal Creek" ten miles north of Tsaya in San Juan County.) Fruitland formation (Maestrichtian?), late Cretaceous.

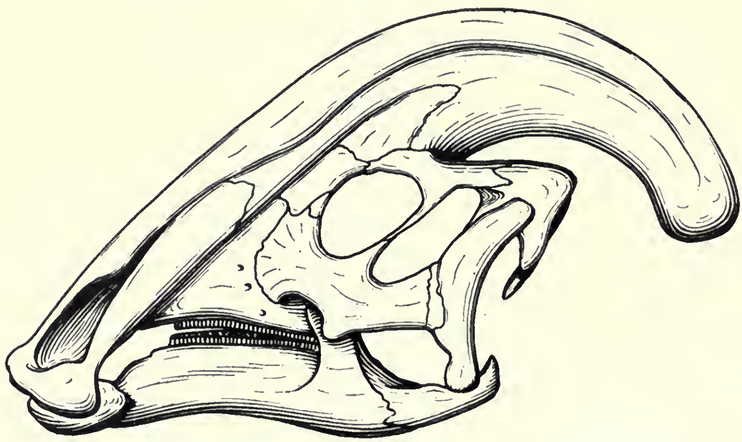

FIG. 84. Restoration of skull of *P. cyrtocristatus;* based on skull of *P. walkeri.* (Approximately × 1/10.)

Skull (figs. 84–86).—Unfortunately, the greater part of the skull is lacking. Only fragments of the dorso-caudal part of the cranium (and a fragment of the left dentary) were collected, together with the complete cranial crest. Recovery of the crest was most fortunate, for this structure is the principal basis for assigning the specimen to a third species of *Parasaurolophus.*

The cranial crest is strongly deflected downward behind the occipital crest instead of sweeping upward in a gentle arc as in *P. walkeri* and *P. tubicen.* Its distal end extends only 260 mm. behind the occipital crest, approximately one third of the extension found in *P. walkeri.* The total length of the superior margin of the crest, measured from the rostral end of the premaxilla to the posterior extremity, exceeds 1425 mm. (the anterior extremities of the premaxillae are missing), as compared with 1733 mm. in *P. walkeri.*

In superficial appearance, the crest (fig. 84) is a rather massive, virtually untapered, laterally compressed cylinder. The rounded distal extremity is approximately 20 per cent smaller in its lateral

and vertical dimensions than is the base of the crest. A distinct longitudinal groove marks the lateral surfaces for nearly the entire length of the crest, reflecting the looped pattern of the enclosed

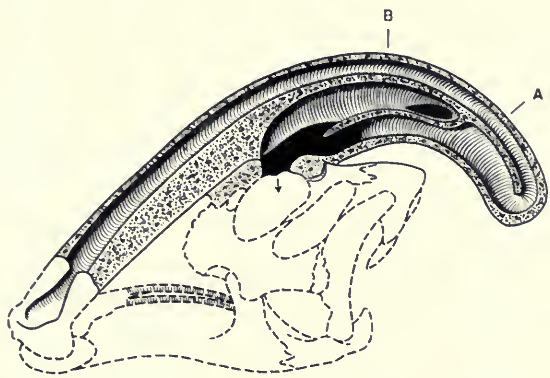

FIG. 85. Restored skull of *P. cyrtocristatus* with left side of crest removed to show narial passages. Note accessory chamber situated between upper and lower tracts. This chamber communicates posteriorly with a similar accessory chamber on right side of crest. These chambers, together with principal narial tracts, lead to a "choanal" canal (arrow) situated at base of crest above interorbital region. A and B indicate location of the two cross sections illustrated in figure 86. Skull restoration based on *P. walkeri*. (Approximately × 1/14; from Ostrom, 1961b.)

narial tubes. Lateral crushing, together with the loss of adjacent elements, has obscured the osteological composition of this structure, but it appears to be composed entirely of a single pair of bones—probably the premaxillae. The nasals, if included in the crest, appear to be small elements located at its base.

Dissection of one side of the crest has revealed the detailed internal morphology of a lambeosaurine crest for the first time. Paired narial passages, separated by a median bony septum, extend along the superior portion for the entire crest length. At the posterior extremity, these passages loop forward beneath themselves, extending forward in the inferior half of the crest to a single opening ("choana") in the interorbital region at the crest base, as illustrated (fig. 85). Although extremely thin, the median septum forms a continuous wall between the paired canals over their entire length. Similarly, a continuous bony wall separates the upper and lower tracts, except at the caudal end of the crest.

A crestal feature which was totally unexpected and which may or may not be present in the other species of this genus, is a pair of elongated, blind cavities located between the upper and lower

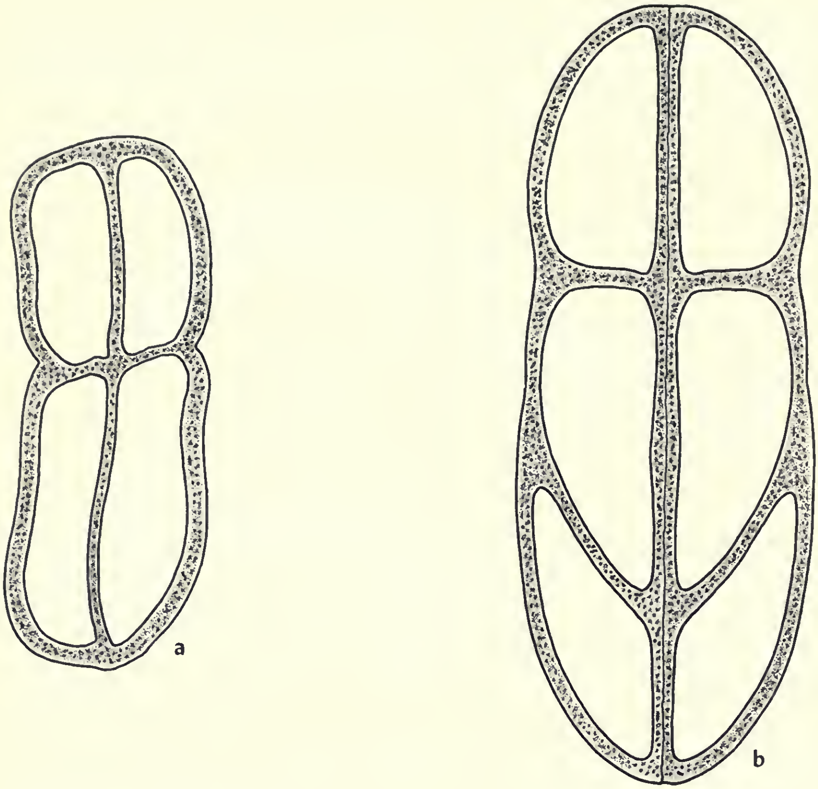

FIG. 86. Cross sections of crest of *P. cyrtocristatus* (from Ostrom, 1961b). Distal section (*a*) as seen in a natural break; proximal section (*b*) is restored (see fig. 85 for location of these sections; approximately × 1/2).

passages. The auxiliary cavities, which extend from the "choanal" region of the crest nearly half way to the crest extremity, communicate with each other at their posterior limits. Their only connection with the principal narial canals is anteriorly at the base of the crest.

Vertebral column (figs. 87–89).—The vertebral column, while incomplete, is sufficiently intact to provide adequate comparison with other hadrosaurian material. The elements preserved include 3 cervicals, 11 dorsals, 8 sacrals and 26 caudal vertebrae. Although some vertebrae are fragmentary, others are very nearly complete.

With only 3 cervicals preserved, it is of course impossible to determine the total number of cervical vertebrae, but relying upon the overall similarity of this specimen with *P. walkeri* we may assume

a total of 13 cervicals. The preserved elements appear to be posterior cervicals, possibly the ninth, tenth, and eleventh. This interpretation is based on comparison of the 3 vertebrae with the cervical series of *P. walkeri* and the establishment of the following points. All 3 cervicals originally bore neural spines, which are now broken off. In the cervical series of *P. walkeri*, the most anterior neural spine (other than that of the axis) occurs on the ninth cervical. The postzygapophyses are strongly developed, curving downward and outward, characteristic of the eighth through thirteenth cervical vertebrae of *P. walkeri*. Most striking of all, however, are the very long and stout transverse processes, which are similar to those processes of the posterior cervicals of *P. walkeri*. These processes extend laterally and slightly downward for approximately 60 mm. beyond the prezygapophyseal facets. In *P. walkeri* the transverse processes are somewhat shorter and more strongly deflected ventrally from the prezygapophyseal facets than in the present specimen.

The strongly opisthocoelous centra (which suggest that these three vertebrae are not the last three cervicals) are slightly flattened dorso-ventrally, somewhat constricted at mid-length and inflated both anteriorly and posteriorly. The zygapophyses are well developed and marked by distinct articular facets. Upon comparison with *P. walkeri*, the zygapophyses in the present specimen are seen to be more widely spaced both transversely and longitudinally. This would apparently have permitted a lesser degree of flexion and abduction of the head in the present specimen.

The preserved dorsal vertebrae (figs. 87, 88) represent a continuous series of posterior elements, probably the seventh through the seventeenth, assuming a total of seventeen dorsal vertebrae in this species as in *P. walkeri*. How many anterior dorsals are missing of course cannot be established, but, with the exception of the first one of the series (the seventh?), all compare very closely with the posterior dorsals of *P. walkeri*. The centra are decreasingly opisthocoelous caudally, with the last two of the series platycoelous. Centrum length also diminishes posteriorly from a maximum of 130 mm. to a minimum of approximately 75 mm. There is a corresponding increase from front to rear in the height and width of the centra. In all of these characters, the current specimen duplicates conditions found in *P. walkeri*.

The first neural spine of the series is pointed and inclined sharply backward (in contrast to the seventh neural spine of *P. walkeri*, which is inclined forward unlike any of the other dorsal spines).

FIG. 87. Dorsal vertebrae of *Parasaurolophus cyrtocristatus*, seen from left side (approximately $\times$ 1/6). *a*, Eighth dorsal vertebra. *b*, Twelfth dorsal vertebra. *c*, Seventeenth dorsal vertebra.

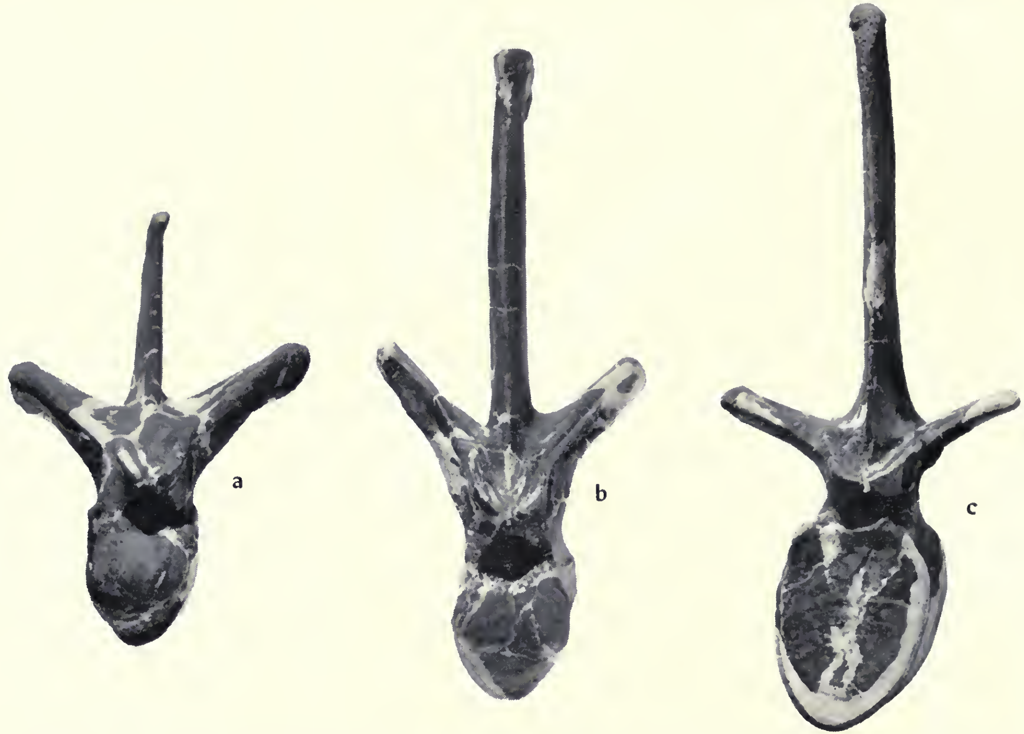

FIG. 88. Dorsal vertebrae of *Parasaurolophus cyrtocristatus*, seen from front (approximately × 1/6). *a*, Eighth dorsal vertebra. *b*, Twelfth dorsal vertebra. *c*, Seventeenth dorsal vertebra.

Successive spines become broader and more nearly rectangular in form and are oriented with a decreasing angle of rake. The last neural spine of the dorsal series is largely perpendicular to its centrum, although in its upper part it does curve slightly forward. With regard to height, there is a pronounced increase in this dimension back to the middle of the preserved series, at which point the trend is reversed and successive spines are slightly shorter. Spine length is always greater than in *P. walkeri.*

The transverse processes of the dorsal series show a progressive change in size and attitude from the front backward. A variable decrease in length coincides with a consistent reduction in the degree of backward rake and upward sweep of the transverse processes. Whereas the processes of the anterior dorsals sweep upward and backward, those of the posterior dorsals extend only slightly upward and laterally. Distinct capitular facets are preserved on the first nine (seventh through fifteenth dorsals?) elements just behind the prezygapophyses high on the neural pedicels at the base of the transverse processes. These features could not be discerned on the last two dorsals preserved, suggesting that the last two dorsal ribs (which are not preserved) may have been holocephalous, as in some primitive ornithischians.

The zygapophyses, unlike those of the cervical series, are placed very close to the mid-line and are quite prominent in their development. The anterior zygapophyseal facets are small and very steeply inclined. Successive vertebrae display larger facets with decreasing inclination. As a result of the progressive shortening of centra lengths, the zygapophyses are more closely spaced toward the rear of the series.

The sacrum consists of eight vertebrae, the centra of which are all firmly fused. Although varying slightly in degree, there is a general increase in the height and width of the sacral centra posteriorly, but there is little if any change in length. Centra of the anterior and posterior sacral vertebrae are almost platycoelous. The sacral transverse processes become increasingly robust and longer from the first to the eighth vertebrae and those of the second through the eighth bear broadly expanded distal extremities that quite probably articulated with, and supported the ilia. Beneath the diapophyses of the six middle sacral vertebrae, thin blades of bone representing the sacral ribs extend downward and outward from the inter-central unions. Distally, adjacent sacral ribs expand and fuse together in a massive, slightly curved iliac bar, the principal bearing surface of the vertebral–pelvic junction.

FIG. 89. Cervical and caudal vertebrae of *Parasaurolophus cyrtocristatus* (approximately × 3/16). *a*, Dorsal view of tenth and eleventh cervical vertebrae. *b*, Right lateral view of two posterior caudal vertebrae.

The neural spines continue the trend established in the posterior dorsals. The first sacral spine is slightly shorter (perhaps due to distortion) than that of the last dorsal vertebra, but it is similar in form, nearly rectangular and square-crested, rising vertically from the neural arch and bending moderately forward near its extremity. Each succeeding spine appears slightly higher, narrower from front to back, and more erect. The eighth sacral spine accordingly is the tallest, narrowest, and straightest of the series.

Twenty-six vertebrae, in varying degrees of preservation, represent our total knowledge of the caudal series (fig. 89). Two of these are badly crushed and quite incomplete, but the large disc-like centrum marks both as anterior caudal vertebrae, perhaps the second and fourth caudals. The remainder of the preserved caudals

form a continuous series, but a number of anterior elements, together with an unknown number of distal vertebrae, are lacking.

Considering the two anterior caudals first, the platycoelous centra are (or were) nearly circular in section with a maximum diameter (width) of about 150 mm. The centrum length is approximately 65 mm. These dimensions are consistent with those of the posterior sacrals. The transverse processes, also like those of the posterior sacrals, extend nearly horizontally outward from the upper lateral surfaces of the centra, rather than from a position high on the neural pedicels as in the dorsal and anterior sacral vertebrae. The neural spine of the larger of these two vertebrae, while incomplete, is quite robust and oval in section rather than blade-like as are the sacral neural spines, and ascends caudally at an angle of approximately 65° from the centrum. The spine of the second of these anterior caudals is similar in all respects except that it angles backward at about 45° from its centrum.

The remaining caudal vertebrae are distinctly different from these first two, with spool-shaped rather than disc-shaped centra, blade-like and caudally directed neural spines, and no transverse processes. It is impossible to say how many caudal vertebrae are represented by the gap between the two large anterior elements and the other 24 posterior caudals, but morphological and dimensional differences suggest that perhaps 15 or more vertebrae are missing. Lull and Wright (1942, p. 79), in describing the caudal vertebrae of *Anatosaurus*, note that the 19 caudals all possess transverse processes. The posterior caudals of *Parasaurolophus walkeri* unfortunately are not known, so no comparison is possible here, but *Corythosaurus casuarius* may have anywhere from 13 to 16 caudals that bear transverse processes. Thus it would appear that the first of these posterior caudals is quite far back in the caudal series.

The posterior caudals are all quite similar in form, but they diminish uniformly in nearly all dimensions. A more rapid reduction posteriorly of centrum height and width relative to length, gives the more distal centra a distinctly spool-like appearance. Although the neural spines are not preserved in all of these caudals, there appears to be a consistent backward rake throughout the series, as well as a progressive reduction in the length of more caudally situated spines. Prezygapophyses are prominently developed at the base of the neural spine in all of the caudals preserved, but the postzygapophyses diminish in size and ultimately completely disap-

pear early in the series. Several complete or near complete haemapophyses indicate that the anterior chevrons are robust, but short. Posteriorly, these become more delicate and elongate, although distally, of course, they must also become consistently shorter.

Ribs.—Cervical ribs are not preserved in this specimen, but quite probably they were similar to those of *P. walkeri*. The thoracic ribs, on the other hand, are well represented by several complete and many fragmentary bones. While not very distinctive, all are dichocephalous, bearing a distinct tuberculum on the outside of the shaft at its point of greatest curvature. (The most caudal ribs are not preserved, but as suggested elsewhere, these may have been single-headed.) Medial to the tuberculum, the shaft curves sharply downward, terminating in a broad, oval capitular facet. Ventral to the tuberculum, the shaft tapers gradually while curving gently medially. The ventral extremity, at least of the anterior thoracic ribs, is marked by an irregular expansion, which probably represents its articulation with the sternal segment. Although only a few ribs are complete, the first six thoracic ribs appear to have been nearly equal in length. The more posterior ribs, however, were successively shorter towards the rear.

Shoulder girdle (fig. 90).—Both scapulae are nearly complete, but neither of the coracoids and none of the sternal elements were recovered. The scapula is a long, but relatively narrow bone which curves slightly toward the rear. The dorsal (posterior) half is distinctly blade-like, rectangular in shape, and very thin and slightly convex laterally. The blade diminishes ventrally toward the glenoid as the scapula narrows (dorso-ventrally) and thickens (transversely). The ventral third thickens to form a massive antero-dorsal facet for the coracoid and a broad ventral glenoid surface. A broad external concavity separates these two articular prominences. The upper ridge (acromion) extends with diminishing prominence from the anterior extremity obliquely across the external scapular surface to the concave ventral margin of the blade at about midlength. Although very similar in form to the scapula of *P. walkeri*, this bone is one of the few elements of the species in question that is smaller than its counterpart in *P. walkeri*, measuring 885 mm. in length as compared to 940 mm. in the Belly River specimen.

Forelimb (figs. 91, 92).—Both humeri are quite complete and in a fine state of preservation. Although slightly larger than those of *P. walkeri*, they are almost identical in form. Rather massive in

FIG. 90. Pelvic and pectoral girdle elements of *Parasaurolophus cyrtocristatus*. *a*, Right ischium, external view; × 1/11. *b*, Right pubis, external view; × 1/8. *c*, Left scapula, external view; × 1/11.

structure, the humerus is slightly sigmoidal in lateral aspect and convex outward in anterior view. The head is not greatly expanded but extends medially as a rather massive ridge situated approximately midway between the lateral and medial tubercles (this condition can best be seen on the right humerus). The most prominent feature of this bone is the very conspicuous deltopectoral crest which extends distally along the latero-anterior surface of the shaft for almost half the length of the humerus. At about mid-length, the deltopectoral crest achieves its maximum development, from which point it abruptly declines and fades into the humeral shaft.

Distally, the radial and ulnar articular condyles (fig. 92) are well-developed convexities, separated by a rather prominent groove that continues proximally along the posterior surface of the shaft as a broad depression. The two condyles are subequal in size, the lateral condyle (capitellum) being slightly broader and less convex than its mate.

The right radius and ulna are nearly complete, but the corresponding left elements are only partially preserved. The radius consists of a nearly straight, cylindrical shaft with slightly flared, oval to circular extremities, the proximal end being gently concave and the distal surface slightly convex. The shaft is ornamented proximally by a broad, postero-lateral ridge and distally by a similar antero-lateral ridge. The former may well represent the area of attachment of the M. supinator, the latter that of the M. extensor carpi radialis. The ulna also is nearly straight and at least distally is similar to the radius, with a subcylindrical shaft and a slightly expanded, convex articular surface. The proximal end, on the other hand, is larger and almost U-shaped in section, with the antero-medial concavity marking the region of radial apposition. The olecranon is greatly expanded and nearly L-shaped in section, its extremity extending some 50 mm. beyond the level of the sigmoid notch.

The manus is represented only by the complete III and IV metacarpals of the right manus and fragments of some left metacarpals. Both of the complete elements are long, cylindrical bones with moderately expanded, convex extremities. The lengths of these elements are given in the accompanying table.

Pelvis (figs. 90, 93).—The ilium in this species does not differ in any important way from the typical hadrosaurian condition, although the posterior iliac blade is relatively somewhat shorter than in most hadrosaurian species. The bone as a whole is quite long (1020 mm.)

FIG. 91. Proximal limb bones of *Parasaurolophus cyrtocristatus*. *a*, Left femur, external view; × 1/11. *b*, Right femur, anterior view; × 1/11. *c*, Left humerus, external view; × 1/6. *d*, Right humerus, anterior view; × 1/6.

FIG. 92. Distal limb bones of *Parasaurolophus cyrtocristatus*. *a*, Right tibia, external view; × 1/11. *b*, Left tibia, anterior view; × 1/11. *c*, Right fibula, internal view; × 1/11. *d*, Left fibula, external view; × 1/11. *e*, Right radius, external view; × 1/6. *f*, Right ulna, external view; × 1/6.

FIG. 93. *a*, Sacrum of *Parasaurolophus cyrtocristatus* viewed from right side; × 1/6. *b*, Left ilium of *P. cyrtocristatus*, external view; × 1/11.

and low, with a long, slender, and slightly recurved anterior process. Near mid-length, the ilium is expanded ventrally into a conspicuous pubic process and a long ischial peduncle, both of which border the acetabular upper margin. These two ventral processes are only partially preserved and cannot be compared adequately with those of *P. walkeri*. The antitrochanter flares out abruptly from the dorsal iliac crest, from which point it is deflected sharply downward lateral to the ischiac process. The antitrochanter is a particularly prominent, thick-edged blade of massive construction that probably provided for the attachment of the ilio-femoralis musculature.

Preservation of both ischia demonstrates once again the apparent reliability of the "footed" ischium as a lambeosaurine character. Although partially restored, the distal extremity clearly flares out ventrally in a conspicuous and rather massive "foot." In fact, this feature is considerably more conspicuous in its development than it is in any of the other crested hadrosaurs. Proximally, the ischial shaft tapers slightly before expanding dorsally into the broad iliac process and ventrally into a rather thin obturator blade and pubic process. A thin plate of bone extending between the pubic and iliac processes defines the postero-ventral margin of the acetabulum. The ventrally directed obturator blade, although incomplete, suggests the presence of a distinct obturator notch, as in *Anatosaurus,* but this cannot be verified with the existing material.

The pubis is quadriradiate in lateral aspect, with a very high, thin prepubic blade, a short, but massive iliac process, and a long, tapering post-pubic shaft. The shaft is straight and rather delicate in appearance and apparently did not closely parallel the shaft of the ischium, because of the very prominent obturator blade that projected ventrally from the proximal end of the latter. The ischial process of the pubis is not complete on either side, but remnants of this structure suggest that rather sturdy processes existed for articulation with the anterior extremities of the ischia. Dorsally, the prominent iliac process provided a loose articulation with the pubic process of the ilium. Between the iliac and ischial processes the posterior margin of the pubis is strongly concave, defining the anterior margin of the acetabulum. The prepubic blade is the most conspicuous feature of this bone, accounting for half of its length and most of its mass. From its anterior margin to the acetabular margin, the blade has a length of 430 mm. and a maximum vertical dimension of 285 mm. However, the blade itself is quite thin, except along its margins, where it is moderately thickened.

Hind limb (figs. 91, 92).—Neither femur is intact, but a rather complete composite can be reconstructed from the remains of the two bones. In both, the shaft is straight, subrectangular in cross section, and quite massive in construction. The head, which is partially preserved in the right femur, is well developed and directed inward and slightly upward. The left femur displays a very large, elongate (antero-posteriorly) "greater trochanter." Separated from this by a deep cleft is a prominent, blade-like "lesser trochanter" on the antero-lateral face of the "greater trochanter." Situated

at about mid-length on the posterior surface of the shaft is a large blade-like fourth trochanter that extends for approximately 300 mm. along the postero-medial surface of the shaft and undoubtedly served as the site of origin for the powerful caudifemoral muscles. The distal condyles, although poorly preserved, nevertheless are very prominent, strongly developed convex articular structures, curving well back behind the shaft of the femur. The groove between these two condyles is largely restored, but there can be little doubt of the double nature of the distal femur extremity.

The right and left tibia are represented by the proximal and distal halves respectively. These opposite halves, when viewed in lateral aspect, indicate a slightly sigmoidal curve for the tibia shaft. A broad and slightly convex cnemial crest extends from front to back across the medial portion of the proximal end and is distinctly separated from a large external condyle. From the broad proximal end, the tibia shaft tapers for approximately three fourths of its length, whereupon it enlarges again, flaring out transversely at its distal end to attain a maximum width of approximately 310 mm. The left tibia displays the well-preserved astragalus as a thin, curved triangular bone firmly united cap-like with the distal tibial condyle. An ascending process of the astragalus reaches upward for a short distance (105 mm.) and is closely applied to the anterior surface of the tibia. It is obvious from these relationships that there was no articular freedom between these two bones and that the ankle was characterized by a well-developed mesotarsal joint.

The distal end of the right fibula is not preserved, but the left fibula is quite complete, although distorted. At about mid-length, the latter bone is bent sharply medially and appears to show some abnormal ossification. It is quite evident that this condition resulted from injury early in the life of the individual. Correcting for this distortion, the fibula probably was a nearly straight, slender bone, of much less robust construction than the tibia. Both extremities are expanded. The proximal end, being the larger of the two, is enlarged antero-posteriorly and is slightly hollowed medially, where it was in close contact with the external surface of the tibia. Distally, the fibula is dilated to a lesser degree transversely. Its antero-medial surface is flattened for articulation with the tibia. The distal fibular surface is moderately convex, probably reflecting a free articulation with the calcaneum; the latter element is not preserved in this specimen and does not appear to have been united with the fibula.

As in the case of the manus, very little can be said of the pes. Portions of only three foot elements are known. These have been identified as the distal end (approximately 310 mm. in length) of metatarsal III, the distorted, but nearly complete metatarsal IV (335 mm.) of the right pes, and a single phalangeal element (possibly the second phalange of the second digit). The metatarsal IV is quite long, with a rather thin shaft, but is broadly expanded at each end. A prominent postero-medial tuberosity marks the shaft at mid-length. Proximally, the articular surface is moderately concave and triangular in plan. The distal condyle, which is bisected posteriorly by a shallow cleft, is strongly convex. The fragmentary metatarsal III is similar in form, at least in the character of its distal end, but it is somewhat larger. The original length of this bone probably exceeded 400 mm.

GENERAL DISCUSSION

As has been noted above, there are no significant differences between the postcranial skeletons of this species and *P. walkeri*. There are of course certain dimensional differences, but these are not, in my opinion, sufficiently different to justify the establishment of a new species. In fact, the skeleton of *P. cyrtocristatus* (fig. 94) is not markedly different from that of any of the larger-crested hadrosaurs. Indeed, the only distinctive feature displayed by the present specimen is the short and abruptly curved cranial crest.

After considering the other lambeosaurine crest varieties, it is quite obvious that the crest of the specimen under consideration is most closely allied with those of *P. walkeri* and *P. tubicen*. The rather elongate, curved, tubular form, together with the disposition of the narial tracts within the crest, is similar in all three specimens, but is entirely distinct from the crest form of other hadrosaurian genera. There are, on the other hand, several unique aspects of the crest in question, which, in the light of all information available at present, warrant the placement of this specimen in a separate species.

First of all, the crest is considerably shorter than those of the other two species of *Parasaurolophus*. Secondly, it is distinct in form, being much more sharply curved backward and downward behind the occipital crest, whereas the crests of both *P. walkeri* and *P. tubicen* curve gently upward and backward. One may argue that such differences in crest form are not worthy of species recogni-

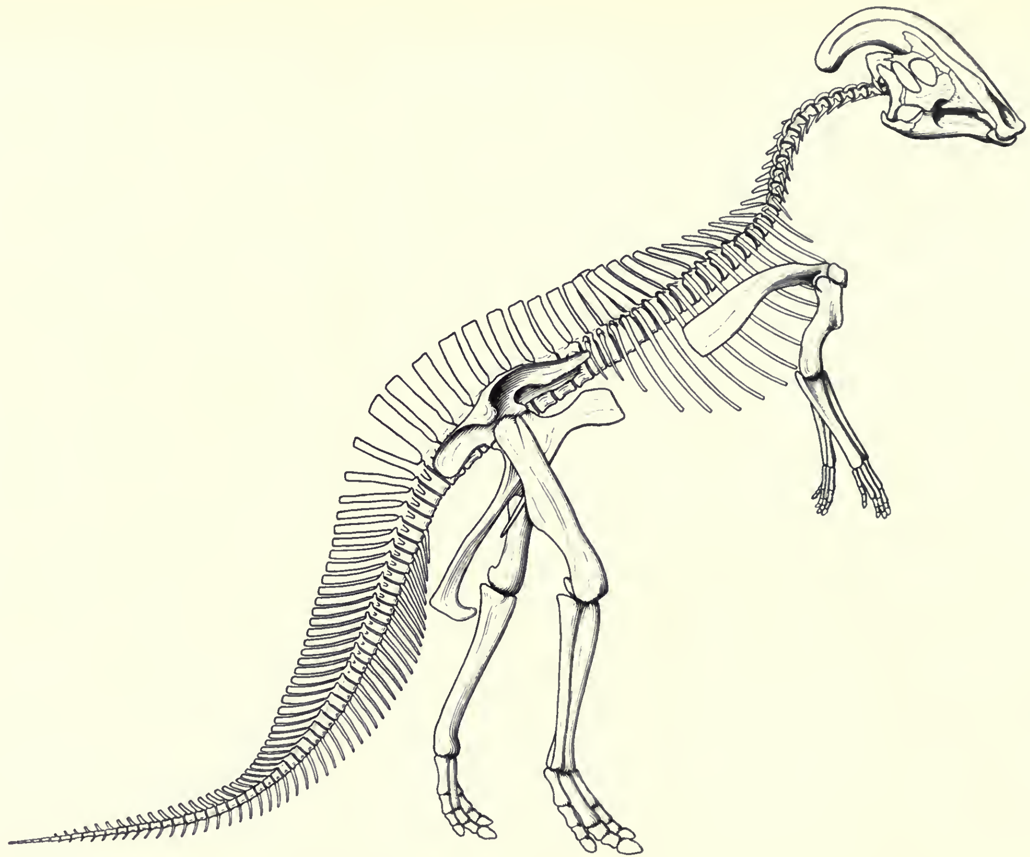

FIG. 94. Reconstructed skeleton of *Parasaurolophus cyrtocristatus;* approximately × 1/35.

tion, since with only a single specimen of each it cannot be demonstrated that these differences are not merely individual or ontogenetic differences. In answer to this, several factors must be considered.

The Lambeosaurinae, or crested hadrosaurs, include a number of species that are surprisingly uniform in most anatomical characteristics. The greatest variation among these specimens is found in the cranial anatomy, specifically in the form and size of the supracranial crests. As a result, over the years, crest morphology has become established as a valuable criterion, indeed the principal means, of distinguishing the many lambeosaurine varieties. In the absence of adequate statistical samples, it is still necessary to rely on morphological differences such as these in order to achieve some degree of order.

Furthermore, evidence does exist refuting the argument that lambeosaurine crest differences are the result of ontogenetic variation. A number of specimens demonstrate that crest morphology is consistent even where there is a range in individual size. For example: *Procheneosaurus erectofrons* is normally smaller than *P. praeceps*, but one specimen (ROM no. 3578) is slightly larger than the largest known specimen of *P. praeceps*, yet morphologically it is distinct from the latter and conforms in all its skull and crest characters to those of *P. erectofrons*. The crest of *Corythosaurus casuarius* is also constant, regardless of whether the specimen is large (AMNH no. 5240) or small (AMNH no. 5338). The three largest lambeosaurine species (*Corythosaurus intermedius, C. bicristatus*, and *C. casuarius*) provide still another example. Existing specimens of these species are approximately of the same size, yet the consistent differences in crest form between specimens of each species permit quick and reliable identification.

Returning to the specimen under consideration, the question of individual variation can only be answered indirectly, since only a single specimen of each of the three *Parasaurolophus* species exists. The possibility that these three specimens represent variants of a single species would seem to be eliminated by the stratigraphic distribution of the specimens. *P. walkeri* was collected from the Belly River of Alberta, *P. tubicen* from the Ojo Alamo of New Mexico and *P. cyrtocristatus* from the Fruitland of New Mexico. Current interpretations of late Cretaceous stratigraphy suggest that none of these units are contemporaneous.

Finally, it is quite certain that the shorter crest of the current specimen is not attributable to ontogenetic variation. As has been pointed out earlier, nearly all postcranial dimensions of the skeleton in question exceed those of *P. walkeri*. Comparison of the postcranial elements of *P. walkeri* and *P. cyrtocristatus* indicates that in spite of the smaller crest of the latter, it was definitely a larger individual. Therefore, the shorter crest cannot be considered a juvenile or immature structure.

SUMMARY

A new lambeosaurine hadrosaur is described from the Fruitland formation (late Cretaceous) of New Mexico. Although only a single specimen is currently known, it is assigned to a new species, *Parasaurolophus cyrtocristatus*, on the basis of its unique crest form. In postcranial anatomy, as well as in general construction of the cranial crest, the specimen is most closely related to *Parasaurolophus walkeri*. The following tables give the comparative measurements of *P. cyrtocristatus* and *P. walkeri:*

Table 1.—COMPARATIVE MEASUREMENTS OF SHOULDER GIRDLE AND FORELIMB

	P. cyrtocristatus mm.	*P. walkeri* mm.
Length of scapula	885	940
Width of scapula	240	248
Length of humerus	565	520
Width of humerus across deltopectoral crest	160	160
Length of deltopectoral crest	305	310
Length of radius	585	496
Length of ulna	665	560
Length of metacarpal III	220	208
Length of metacarpal IV	250	195

Table 2.—COMPARATIVE MEASUREMENTS OF PELVIC GIRDLE AND HIND LIMB

	P. cyrtocristatus mm.	*P. walkeri* mm.
Length of ilium	975	1020
Length of anterior iliac process	440	445
Length of pubis	810?	894?
Length of prepubis (from acetabulum)	430	516
Width of prepubis	285	260
Length of ischium	1040	—
Length of femur	1105	1032
Length of tibia	—	—
Length of fibula	890	—
Length of metatarsal IV	335	—

TABLE 3.—COMPARATIVE MEASUREMENTS OF DORSAL VERTEBRAE

Number of dorsal vertebra	Length of neural spine		Length of diapophysis		Length of centrum		Height of centrum	
	P. cyrtocristatus mm.	*P. walkeri* mm.	*P. cyrtocristatus* mm.	*P. walkeri* mm.	*P. cyrtocristatus* mm.	*P. walkeri* mm.	*P. cyrtocristatus* mm.	*P. walkeri* mm.
1	—	160	—	130?	—	—	—	—
2	—	165	—	120	—	—	—	—
3	—	170	—	120	—	—	—	—
4	—	—	—	135	—	—	—	—
5	—	180	—	135	—	—	—	—
6	—	140	—	120	—	—	—	—
7	280	140	140	110	130	—	—	—
8	375	295	120	95	130	—	80	—
9	400	290	120	100	130	—	80	—
10	420	305	90	95	135	—	80	—
11	410	305	—	100	125	—	80	—
12	410	300	105	110	125	—	90	—
13	—	285	—	120	105	—	90	—
14	415	270	115	150	100	—	90	—
15	355	275	105	120	100	—	90?	—
16	—	280	—	120	—	—	—	—
17	345	—	105	180?	80	—	130?	—

TABLE 4.—COMPARATIVE MEASUREMENTS OF SACRAL VERTEBRAE

Number of sacral vertebra	Length of neural spine *P. cyrto-cristatus* mm.	*P. walkeri* mm.	Length of centrum *P. cyrto-cristatus* mm.	*P. walkeri*
1	310	310	80	—
2	330	310	95	—
3	340	305	85	—
4	340	310	85	—
5	330	330	80	—
6	—	370	90	—
7	—	405	85	—
8	—	—	75?	—

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